Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	File No. ______
Request For Declaratory Ruling	)	
Authorizing the Use of OFDM Modulation	)	MM Docket No. 97-217
in MDS and ITFS Services	)	

PETITION FOR DECLARATORY RULING

Clarity Wireless, Inc. ("Clarity") hereby requests the Commission to authorize the use of Orthogonal Frequency Division Multiplexing ("OFDM") digital modulation with respect to the provision of MDS and ITFS service.

I. INTRODUCTION

Clarity was founded to develop breakthrough wireless data communications products for the computer networking and Internet service markets. Clarity's wireless modem technology is the result of four years of research and development leading to revolutionary new digital signal processing ("DSP") and radio frequency ("RF") techniques that Clarity believes will set new performance and cost standards in wireless communications. For example, Clarity's products will communicate at a data rate that is an order of magnitude greater than today's state-of-the-art wireless products even in much more heavily obstructed links.

Existing MDS and ITFS two-way digital communication equipment solutions generally are based on quadrature amplitude modulation ("QAM") or vestigial sideband modulation ("VSB") with equalization. These types of technology are not optimal for achieving very high data rates in obstructed conditions that lead to severe multipath signal propagation. Since high data rate QAM solutions are not robust to multipath, the deployment of long-range, high data rate systems is limited to line-of-sight ("LOS") scenarios -- *i.e.*, applications that account for a small fraction of the potential market for wireless computer networking and multimedia communication equipment. Some of the large markets that are not optimally served by present wireless products include campus area networking (corporate facilities, universities, hospitals, airports, etc.), high-speed Internet connections for metropolitan area consumers, and high-speed wireless local loop operations where LOS propagation is unavailable.

Clarity's unique RF and DSP technology solves the multipath problem so that data rates from 10 Mbps to 155 Mbps can be achieved *even when line-of-sight paths are not available*. This technology opens up the possibility of deploying high-speed wireless data networks at lower cost than with technologies that require LOS paths. Cellular and microcellular architectures, for example, can be used without the need to place antennas on tall towers. Instead, antennas can be placed in convenient, unobtrusive locations that facilitate inexpensive installations, while also providing wireless services at data rates that exceed those that can be achieved with other existing wireless products.

Clarity shares the vision expressed in the Commission's *Two-Way Notice*[1] that the MDS and ITFS bands are well suited to high-speed two-way data communications services. Furthermore, Clarity believes that the best way to provide those services is with a classic cellular or microcellular network deployment in which a multitude of low- and medium-power base stations and remote stations are used to provide coverage to customers. Clarity's technology has

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1 In the Matter of Amendment of Parts 1, 21 and 74 to Enable Multipoint Distribution Service and Instructional Television Fixed Service Licensees to Engage in Fixed Two-Way Transmissions, *Notice of Proposed Rulemaking*, 12 FCC Rcd 22174, 22187 (1997) ("Two-Way Notice").

been developed to advance and promote this Metropolitan Area Network ("MAN") service model for the MDS and ITFS bands. Accordingly, Clarity has a vital interest in supporting regulatory measures that will facilitate two-way wireless data operations, including approval of a modulation approach necessary to achieve that vision.

II. THE COMMISSION SHOULD APPROVE OFDM AS A DIGITAL MODULATION METHOD THAT MAY BE USED BY MDS AND ITFS LICENSEES

In order to develop cellular and microcellular networks that are simple and cost-effective, Clarity believes that it is critically important for the Commission to promote MDS and ITFS radio equipment solutions that enable robust broadband data communications performance in the presence of multipath signal propagation. Today, MDS two-way digital communication products is based largely on standard cable modem technology that is designed to work in coaxial cable deployments, not in multipath wireless applications. This present equipment deficiency forces service providers to consider only LOS deployment scenarios that involve expensive and unsightly high altitude tower-top deployments for response station hubs. However, recent developments in Orthogonal Frequency Division Multiplexing ("OFDM") technology provide the required means for achieving very high data rates in severe multipath conditions, which in turn reduces greatly the need to place antennas on tall towers.

In its *Digital Declaratory Ruling*, the Commission expressly authorized the use of QAM and VSB digital modulation in the MDS and ITFS services.[2] Although the Commission did not consider the use of other digital modulation methods in the context of that proceeding,

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2 *See* In the Matter of Request for Declaratory Ruling on the Use of Digital Modulation by Multipoint Distribution Service and Instructional Television Fixed Service Stations, 11 FCC Rcd 18839 (1996) ("Digital Declaratory Ruling").

the Commission stated that it would consider future requests for declaratory rulings where the requesters submit appropriate data to demonstrate that other modulation techniques can be used in a manner that will not interfere with MDS and ITFS analog and digital operations.[3]

By this petition, Clarity requests the Commission to expressly authorize MDS and ITFS licensees to use OFDM as a digital modulation method. Clarity has retained the firm of Hardin and Associates to assist in validating that OFDM "easily complies with the existing 45-dB co-channel and 0-dB adjacent-channel requirements specified in current MDS and ITFS rules."[4] In order to unlock the potential of MDS and ITFS spectrum for two-way operations, and to enable MDS and ITFS operators to take advantage of a potential paradigm shift in broadband wireless communications, Clarity urges the Commission to find that the use of OFDM modulation will serve the public interest, convenience, and necessity.

A. Overview Of ODFM Modulation and Benefits

In 1996, the Commission predicted that "the introduction of digital technology will enhance the service of wireless cable operators by allowing opportunities for increased channel capacity and programming choices . . . and the provision of video, voice, and data services that cannot be offered currently."[5] That prediction is accurate. Recent developments in OFDM technology provide the means for wireless cable operators to achieve very high data rates

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3 *Id.* at 18848 & n. 31.

4 Hardin and Associates, "Engineering Statement in Support of a Petition for Declaratory Ruling on the Use of OFDM Modulation in MDS and ITFS Services" (July 1998), at 1 ("Hardin Study"). The *Hardin Study* is attached hereto as Exhibit 1.

5 *Digital Declaratory Ruling*, 11 FCC Rcd 18839, 18842 (1996) (footnote omitted).

in severe multipath conditions -- a development that Clarity believes will lead to revolutionary new uses for MDS and ITFS spectrum.

As described in the *Hardin Study*, OFDM modulation is generated by conveying digital information over a series of carriers closely spaced in frequency rather than by modulating all of the information on a single carrier frequency.[6] Each carrier is modulated with a portion of the data to be transmitted rather than the entire information signal. The modulation on each of the carriers is typically a form of QAM modulation, *e.g.* QPSK, 16-QAM, or 64-QAM. According to the *Hardin Study*, the OFDM modulation process can be viewed as "a parallel transmission of information on multiple carriers versus a serial transmission of information on a single carrier."[7]

In order to improve the ability to discriminate one carrier from the next, OFDM spaces the carriers so that the energy in the spectrum of each carrier is at a minimum at the frequency of the two adjacent carriers. This orthogonality provides isolation between adjacent carriers and thus helps to prevent interference between the information carried on each.[8]

The data stream modulated on the OFDM waveform incorporates coding to make the OFDM signal even more robust in the presence of multipath and interference -- often referred to in HDTV circles as "COFDM."[9] Clarity refers to its proprietary method of coding as Vector

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6 *See Hardin Study* at 2.

7 *Id.*

8 *Id.*

9 *Id.*

OFDM ("VOFDM"). Adding coding to the data modulated on the RF carriers does not change the spectral characteristics of the RF signal.[10]

The fundamental advantages of OFDM as a modulation method include tremendous resistance to multipath fading and good spectral efficiency.[11] For most modulation schemes, the effects of multipath on data communications in a wireless environment are the most difficult to overcome. Moreover, each receive site path is different and multipath characteristics can vary dramatically. Even in the presence of severe multipath propagation, however, OFDM signals remain free of inter-symbol interference ("ISI") and no equalization processing is required. This allows very high data rates in channels that would otherwise be unusable with other cost-effective types of modulation.[12] Clarity's VOFDM technology provides even greater benefits along these lines.

In addition, because OFDM is created from multiple narrowband carriers, it can provide very high spectral efficiency while remaining inside required emissions masks. As the *Hardin Study* points out, these "inherent advantages allow equipment to be less expensive than with other modulation schemes because the computational complexity of channel equalization is avoided and filtering requirements are reduced."[13] They also reduce the cost of deploying wireless data networks. OFDM's robust performance in the presence of multipath means that LOS paths are unnecessary, permitting cellular or microcellular networks to be deployed without

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10 *Id.*

11 *Id.*

12 *Id.*

13 *Id.*

placing antennas on tall towers.[14] Instead, smaller, unobtrusive antenna installations can be used that are far less costly than tall-tower installations and far more community-friendly.[15]

B. OFDM Easily Complies with Interference Requirements

Clarity and Hardin & Associates have conducted tests of the compatibility of OFDM with television signals in the MDS and ITFS bands. The description and results of this testing are attached in the *Hardin Study,* which concludes that the interference potential of the OFDM waveform is consistent with the interference potential of the 64-QAM and 8-VSB signals tested in the *Digital Declaratory Ruling* proceeding. Indeed, the *Hardin Study* finds that the OFDM signal "*easily complies*" with the 45-dB co-channel and 0-dB adjacent-channel interference protection requirements specified in the Commission's rules.[16]

As explained in the *Hardin Study*, the test procedure employed to verify OFDM's consistency with the *Digital Declaratory Ruling* and FCC rules was extremely conservative in its methodology. OFDM waveforms were used which came as close as possible to filling the FCC emissions masks. A typical OFDM waveform exhibits spurious emission that is better than the FCC emission masks. Therefore, a tremendous effort was put into *degrading* the spurious response of typical OFDM waveforms so that they would be comparable to the allowable FCC emission masks.[17] Because even these purposefully degraded waveforms easily satisfy co-

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14 *Id.*

15 *Id.*

16 *Hardin Study* at 8 (emphasis added).

17 *Id.* at 7.

channel and adjacent-channel interference protection requirements, *any* OFDM waveform that stays within the FCC emissions mask will meet these requirements. [18]

III. CONCLUSION

Clarity urges the Commission, via the grant of this petition, to facilitate the introduction of OFDM as a Commission-sanctioned modulation approach for the wireless cable industry. The Commission has encouraged parties to "identify different digital modulation schemes that could be useful in MDS and ITFS."[19] Clarity believes that, given the fact that multipath RF signal propagation is an inherent limitation on data rates that can be achieved today with *every* existing product technology, the introduction of OFDM into wireless cable operations will be a breakthrough of enormous benefit to industry and the consuming public.

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18 It should also be noted that any coding applied, including Clarity's highly beneficial VOFDM technique, will not change the spectral characteristics of the OFDM waveforms. Therefore, the extra benefits of such coding techniques are available with no change in adjacent channel or co-channel interference characteristics.

19 *Notice,* 12 FCC Rcd at 22187-88, ¶ 30.

For the reasons set forth herein, Clarity respectfully requests the Commission to authorize the use of OFDM digital modulation in connection with MDS and ITFS operations.

Respectfully submitted,

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EXHIBIT 1

Engineering Statement in Support of a Petition for Declaratory Ruling on the Use of OFDM Modulation in MDS and ITFS Services

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Introduction

Hardin and Associates, Inc. has been retained on behalf of Clarity Wireless, Inc., to test and report on the co-channel and adjacent channel interference potential of digital Orthogonal Frequency Division Multiplexing (OFDM) modulation into analog NTSC video and audio. This testing was conducted to show that OFDM modulation easily complies with the existing 45-dB co-channel and 0-dB adjacent-channel requirements specified in the current MDS and ITFS FCC rules. This testing is consistent with previous testing on the use of QAM and VSB modulations as approved in the Declaratory Ruling and Order, Docket No. DA 95-1854, 11 FCC Rcd. 18839 (1996) ("*Digital Declaratory Ruling*").

Clarity Wireless, Inc. was founded to develop breakthrough wireless products for the data communications industry. The current generation of wireless data communication products is not capable of high data rates because multipath signal propagation is an inherent limitation to the data rates of these products. These products also require line-of-site ("LOS") which affects the amount of subscriber coverage that can be achieved. Clarity's products will communicate at a data rate that is an order of magnitude greater than today's state-of-the-art wireless products even in much more heavily obstructed ("non-LOS") links.

Clarity's wireless modem technology is the result of four years of research and development leading to revolutionary digital signal processing (DSP) that will set new performance and cost standards in wireless communications. Clarity's baseline waveform is based on Orthogonal Frequency Division Multiplexing (OFDM) modulation techniques.

Overview of OFDM Modulation

OFDM modulation is generated by conveying digital information over a series of carriers closely spaced in frequency rather than modulating all of the information on a single carrier frequency. Each carrier is modulated with a portion of the data to be transmitted rather than the entire information signal. The modulation on each of the carriers is typically a form of QAM modulation (QPSK, 16-QAM, or 64-QAM, for example). One way to look at this process is that it is a parallel transmission of information on multiple carriers versus a serial transmission of information on a single carrier.

In order to improve the ability to discriminate one carrier from the next, OFDM spaces the carriers so the energy in the spectrum of each carrier is at a minimum at the frequency of the two adjacent carriers. This orthogonality provides isolation between adjacent carriers and therefore helps to prevent interference between the information carried on each.

Coding is incorporated into the data stream modulated on the OFDM waveform to make the OFDM signal even more robust in the presence of multipath and interference. This is often referred to in HDTV circles as COFDM. Clarity Wireless refers to its proprietary method of coding as Vector OFDM ("VOFDM"). Adding coding to the data modulated on the RF carriers does not change the spectral characteristics of the RF signal.

OFDM modulation has two RF characteristics which can be varied to achieve the desired performance characteristics for a particular application: (i) the number of carriers utilized, and (ii) the modulation density used on each carrier. For a fixed channel bandwidth, as more carriers are added to the OFDM waveform, the bandwidth available to each carrier will decrease. Having more carriers is desirable in order to reduce the symbol rate, thereby making the modulation immune to the effects of multipath and allowing very high data rates in multipath channels. Increasing the modulation density has the effect of further improving the data capacity but at the expense of increased requirements for high signal-to-noise or signal-to-interference ratios. The choices for both of these characteristics are greatly influenced by the choice of coding. Therefore system level tradeoffs must be made for each application and the expected propagational and interference conditions.

Fundamental advantages of OFDM include its tremendous resistance to multipath fading and good spectral efficiency. For most modulation schemes, the effects of multipath in a wireless environment on data communications are the most difficult to overcome. Each receive site path is different and multipath characteristics can vary dramatically. However, even in the presence of severe multipath propagation, OFDM signals remain free of inter-symbol interference ("ISI") and no equalization processing is required, allowing very high data rates in channels that would otherwise be unusable with other cost-effective types of modulation. Clarity's V-OFDM technology provides even greater benefits along these lines.

And because OFDM is created from multiple narrowband carriers, it can provide very high spectral efficiency while remaining inside required emissions masks. These inherent advantages allow equipment to be less expensive than with other modulation schemes because the computational complexity of channel equalization is avoided and filtering requirements are reduced.

These advantages also reduce the cost of deploying wireless data networks. OFDM's robust performance in the presence of multipath means that line-of-sight ("LOS") paths are not necessary and cellular or microcellular networks can be deployed without placing antennas on tall towers. Smaller, unobtrusive antenna installations can be used which are far less costly than tall-tower installations and far more community-friendly.

Spectral Characteristics of OFDM

As mentioned above, the number of RF carriers used in the generation of the OFDM signal and the modulation technique utilized on each carrier are variables which can be adjusted depending on the application. Tradeoffs between capacity and the robustness of the received signal level with respect to multipath and interference must be made for each application. However, the OFDM waveform maintains a uniform spectrum independent of the number of carriers or the modulation used on each carrier. Therefore, the interference potential of an OFDM waveform will be independent of the number of carriers and the modulation technique used on each carrier.

In order to prove the independence of the interference potential, tests were conducted for two different OFDM waveforms. The first waveform was generated using 256 carriers and 4-QAM (QPSK) modulation on each carrier. The second waveform was created using 4096 carriers and 64-QAM modulation. All co-channel and adjacent channel testing was performed for both of these OFDM signals.

Test Process

The process used to test the interference potential of the OFDM waveform was similar to the process used in the testing for the *Digital Declaratory Ruling* previously approved by the Commission with the exceptions noted below. A test setup was created whereby adjacent or co-channel interference from an OFDM signal to a standard NTSC signal could be generated. A viewing area was constructed where a team of expert viewers was used to judge the perceptibility of the interference over a variety of television receivers. The testing was run at cable TV frequencies instead of the microwave frequencies used in the *Digital Declaratory Ruling*. However, the spectral mask of the channels being tested was maintained as per the *Digital Declaratory Ruling*.

Tests were run to determine several different levels of interference perceptibility, once again in the same manner as in the *Digital Declaratory Ruling*. Video measurements were conducted to determine the level of interference required to reach the threshold of visibility ("TOV") and CCIR Grade-4 level[1] as described below in the section titled "Video Measurements." In addition, audio tests were performed to determine the level of degradation in distortion and stereo separation.

Testing was not performed on a series of set-top converters as was conducted for the *Digital Declaratory Ruling*. If the data submitted with the *Digital Declaratory Ruling* are carefully reviewed, one finds that the most sensitive portion of the testing was for the

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[1] CCIR Recommendation 500, "Method for the Subjective Assessment of the Quality of Television Pictures." (Now defined under new nomenclature: ITU/R/BT Recommendation 500.)

television receivers without a set-top converter involved. For co-channel interference there was very little difference between the television receivers and the set-tops. However, the television receivers alone always showed evidence of interference before the set-top converters. In the adjacent channel case, the additional filtering in the set-top IF section was always an additional aid in rejecting the digital interference. Therefore, testing only a series of television receivers represents a worst case analysis.

Video Measurements

Testing was conducted to determine the level of co-channel and adjacent channel interference from an OFDM signal that generated Threshold of Visibility (TOV) and CCIR Grade-4 picture quality. The TOV is the point at which an interfering signal first becomes visible in a picture to a team of expert subjective viewers. CCIR Grade-4 picture quality is defined as interference that is perceptible, but not annoying. Grade-4 impairment was judged by creating interference into a reference television with a carrier-to-noise of approximately 40 dB in a 6-MHz bandwidth. The receivers under test were then compared with this reference signal to determine the level of the undesired signal to give Grade-4 picture quality.

Audio Measurements

Audio measurements were conducted to determine the degradation in harmonic distortion and stereo separation by the OFDM interference. Three of the five television receivers tested had internal stereo decoders with external left and right audio output jacks. Total harmonic distortion plus noise ("THD+N") was measured on each of the output jacks and the worst case number recorded. In all cases the level of distortion on the right and left channels was insignificant.

Stereo separation was measured by modulating the left channel of the stereo signal with a 400-Hz tone while maintaining silence on the right channel. The level of the 400-Hz tone that leaked into the right channel was then expressed as a ratio to the level of the tone in the left channel. The audio level of the television receivers was adjusted for maximum separation for each test.

Measurements of distortion and separation were made with no interference present, with the interference at the TOV level, and with the interference at CCIR Grade-4 level.

Spectral Mask

The spectral mask required for use with digital modulation was specified by the Commission in the *Digital Declaratory Ruling*. The spectral mask requires the digital signal be attenuated 38 dB at the channel edges, linearly attenuated to 60 dB down 3

MHz away from the channel edges, and attenuated at 60 dB down for all other frequencies. These attenuation values are measured relative to the flat portion of the digital signal. For all of the testing conducted on the OFDM signal, this spectral mask was utilized. Attached as Figures 1 through 4 are spectrum analyzer plots of the OFDM signals used in the testing, which show compliance with the *Digital Declaratory Ruling* spectral mask requirements.

Power Measurement

The power of the analog and digital signals was measured as described in the *Digital Declaratory Ruling.* The peak power of the NTSC video signal was compared to the average power of the digital signal to generate the interference ratios.

Equipment Setup

Attached as Figure 5 is a block diagram of the test equipment setup. Attached as Appendix A is a list of the test equipment used in the setup. Attached as Appendix B are pictures of the test equipment used in the setup. This setup allowed testing of co-channel interference from an OFDM waveform on RF channel 4. Adjacent channel testing was conducted by placing OFDM signals on channels 2 and 4 and the NTSC signal on channel 3. For all adjacent-channel testing, both the upper and lower OFDM signals were simultaneously present.

OFDM Signal Generation

The OFDM waveforms used for these tests were generated as shown in Figure 5. The test waveforms were calculated on a PC prior to the tests and were programmed into a Tektronix AWG 2021 Arbitrary Waveform Generator. Running with a sample rate of 250 MHz, the arbitrary waveform generator supplied analog waveforms directly at the television channel frequencies of 54-60 MHz for TV Channel 2, and 66-72 MHz for TV Channel 4. The output of the generator was filtered with an 81-MHz low-pass filter to remove aliases, an attenuator was used to match the 50-ohm generator and low-pass filter output to the 75-ohm impedance of the television equipment used in the tests, and a band-pass channel filter was used to keep the spectrum of the test signal inside the FCC spectral mask.

Two representative OFDM waveforms were used for these tests: (1) OFDM with 256 carriers and 4 QAM (QPSK) modulation on each carrier, and (2) OFDM with 4096 carriers and 64-QAM modulation on each carrier.

In conducting the tests, waveforms were used which came as close to filling the FCC emissions mask as possible. That way the Commission can be satisfied that this test reflects the worst possible case of OFDM modulation -- i.e., if these waveforms meet the required co-channel and adjacent-channel D/U thresholds, then *any* OFDM waveform will meet the required D/U thresholds. Consequently, a tremendous amount of effort was put into *degrading* the spurious response of the waveform programmed into the arbitrary waveform generator so that the spectrum of the signal after passing through the low-pass and band-pass filters matched the FCC emissions mask as closely as possible. (The degraded spectrum was created by using digital filters that reversed the effects of the output band-pass channel filter.) *Without this tremendous effort to degrade the spectrum, the natural spectrum of the OFDM waveforms would have been considerably cleaner than required by the FCC emissions mask and would have resulted in even less interference than measured in this test.*

NTSC Signal Generation

The NTSC video was generated by an S-VHS video tape deck. All tests were run using live video from a tape which provided excellent picture quality. A video generator was used to align and calibrate the test setup.

Receive and Monitoring System

The outputs of the OFDM and NTSC generation systems were combined with a passive combiner and then distributed to each of the television receivers through a passive splitter. The level of the RF signal delivered to each television receiver was approximately +15 to +20 dBmV. Each of the receivers was placed on a table at equivalent heights and the expert viewers were seated 5 to 6 viewing heights away. The lighting in the room was turned off so as to make the sensitivity to interference more severe.

In order to establish a reference signal to judge CCIR Grade-4 performance, a reference television was used. A noise generator was used to generate random noise into the reference television and the level of the noise was set to approximately 40 dB C/N. This represents CCIR Grade-4 picture quality.

Test Results

Attached as Figures 6 and 7 are summaries of the results of the testing for both OFDM signals.

The results of co-channel interference testing show the following:

- The Threshold of Visibility (TOV) for both the 4096- and 256-carrier signals occurs at approximately 44 dB D/U.

- CCIR Grade-4 picture quality occurred 2 to 5 dB below TOV.

- The co-channel audio measurements showed virtually no measurable change in distortion or separation due to the OFDM signal.

The results for adjacent-channel performance were similar to the co-channel results:

- The TOV did not occur until the interference was significantly greater than the desired signal (-3 to -7 D/U).

- Again, adjacent-channel audio measurements showed virtually no measurable change in distortion or separation due to the OFDM signal.

Conclusions

OFDM modulation easily complies with the existing 45-dB co-channel and 0-dB adjacent-channel D/U requirements specified in the current MDS and ITFS FCC rules. For both co-channel and adjacent-channel conditions, video interference from OFDM is below the Threshold of Visibility and audio interference is virtually not measurable.

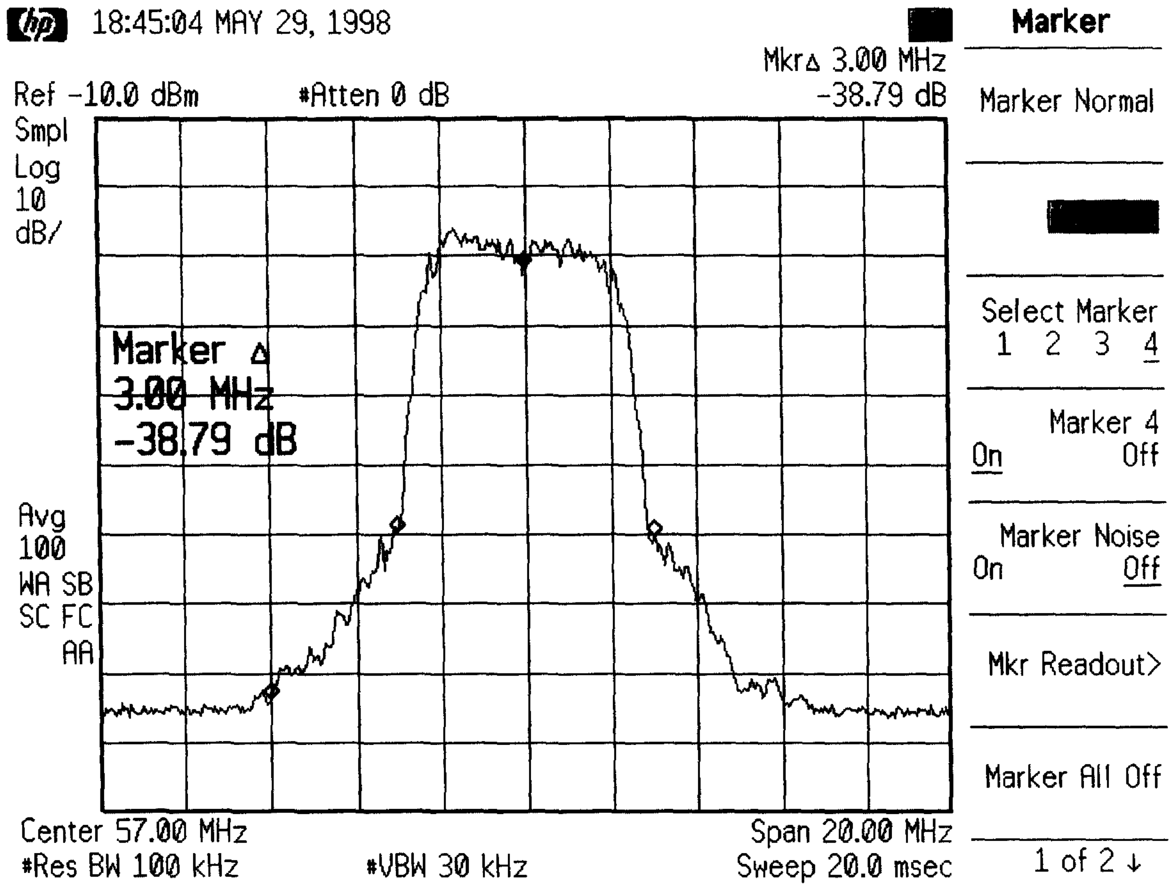


Figure 1. RF channel 2, 256 Carriers, 4 QAM (QPSK)

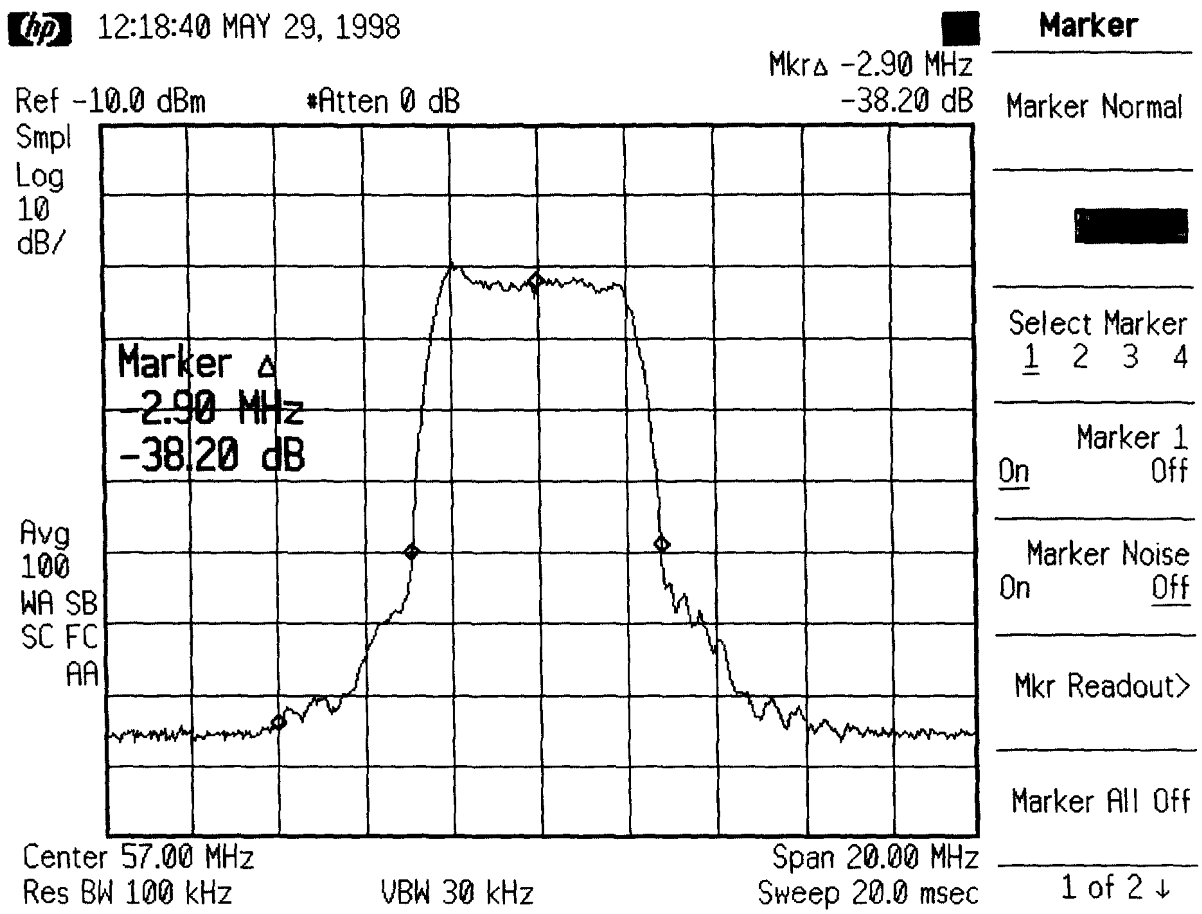


Figure 2. RF channel 2, 4096 Carriers, 64 QAM

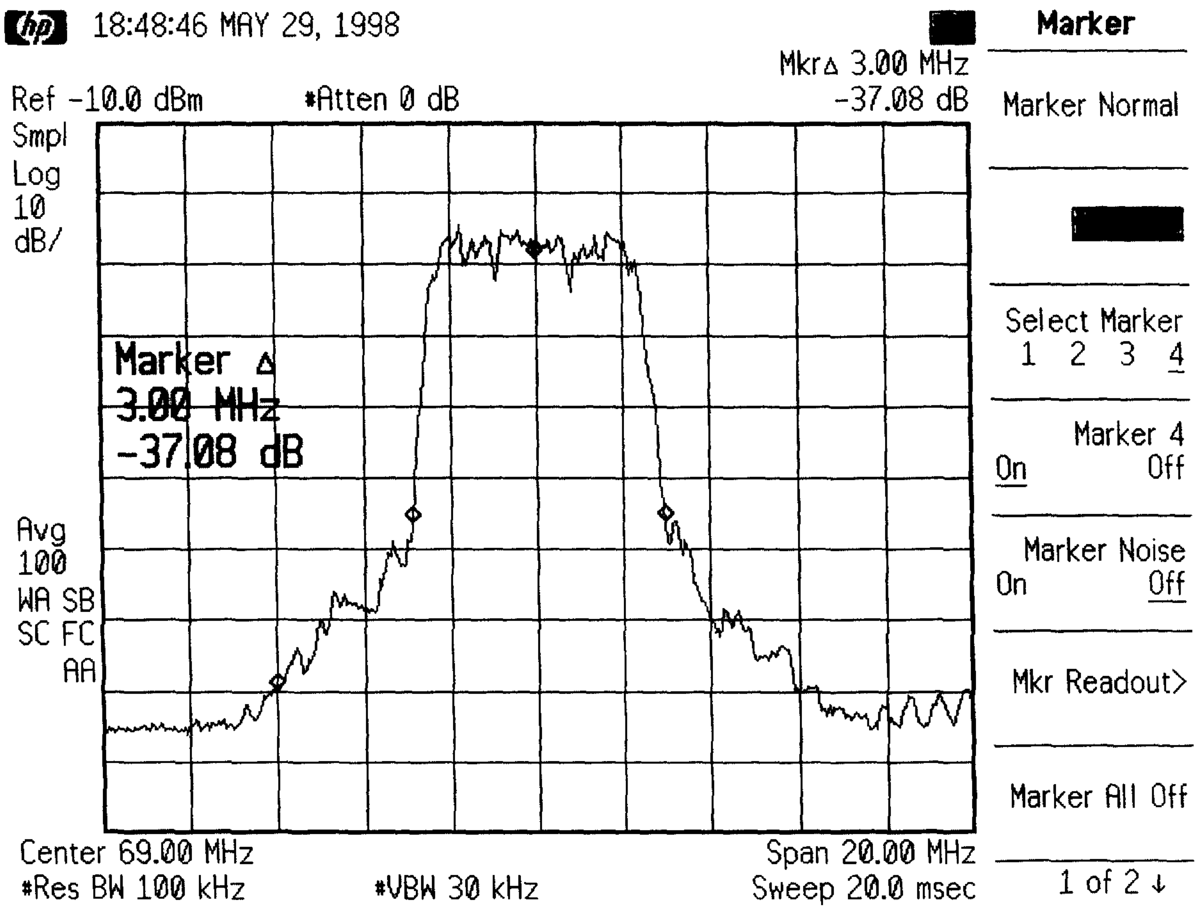


Figure 3. RF channel 4, 256 carriers, 4 QAM (QPSK)

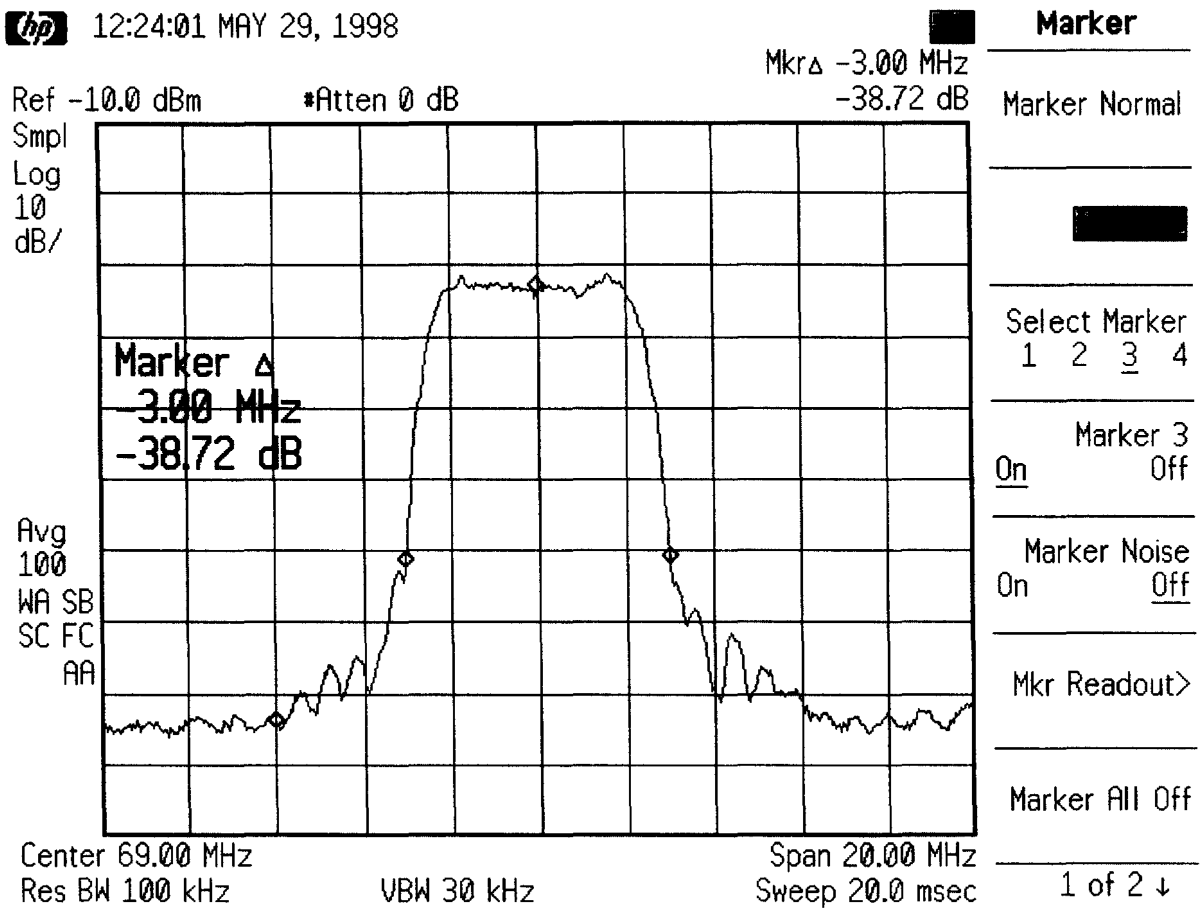
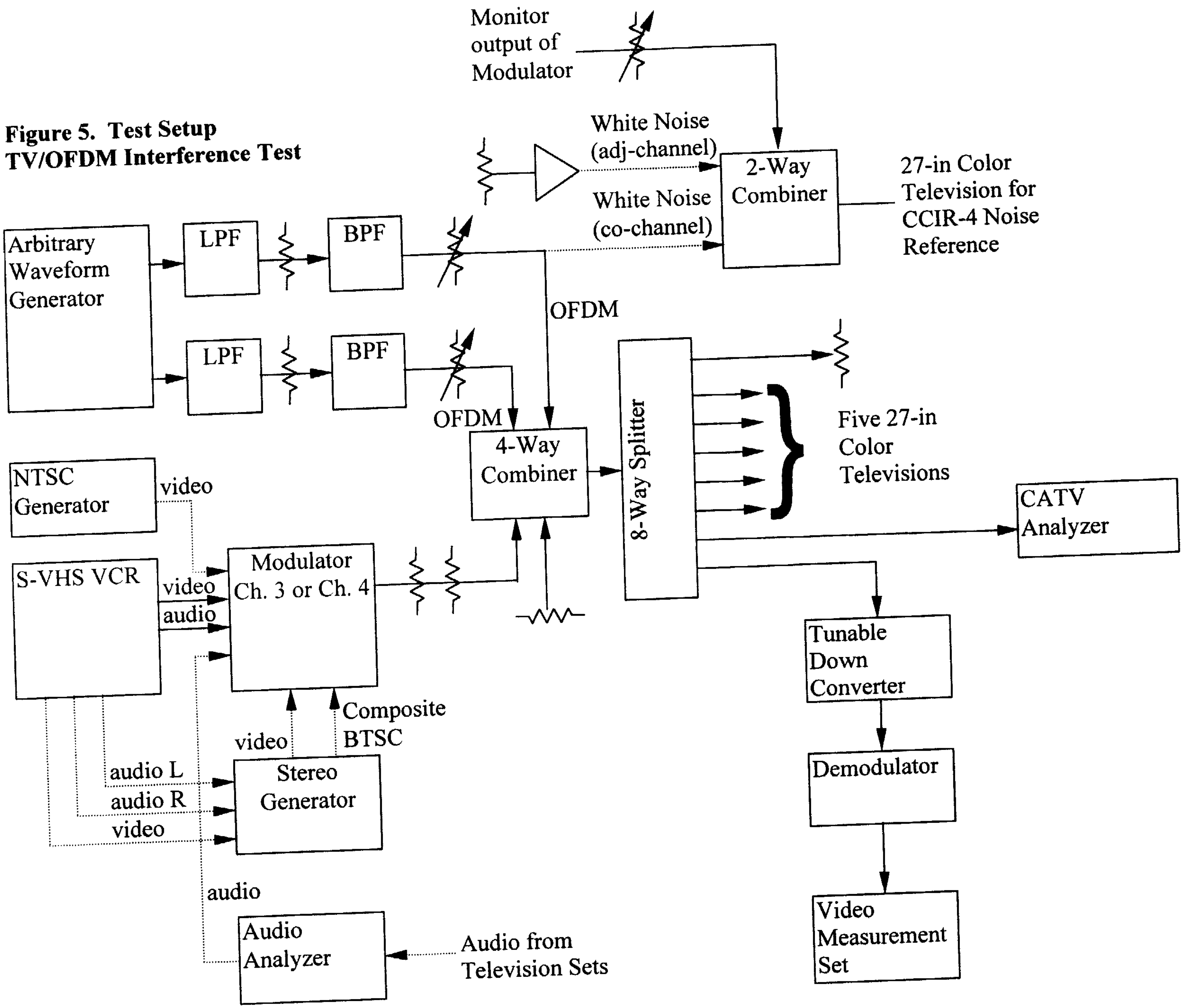


Figure 4. RF channel 4, 4096 carriers, 64 QAM

Figure 5. Test Setup
TV/OFDM Interference Test



4096 Carriers, 64 QAM	TV-1	TV-2	TV-3	TV-4	TV-5	Mean	Std Dev	Median	Max	Min
Co-channel:										
D/U @ TOV	40.7	44.7	43.7	43.7	42.7	43.1	1.52	43.7	44.7	40.7
D/U @ CCIR 4	39.7	41.7	41.7	37.7	36.7	39.5	2.28	39.7	41.7	36.7
Audio THD+N	N/A	1.13	0.6	N/A	1.01	0.91	0.28	1.01	1.13	0.60
Audio THD+N @ TOV	N/A	1.13	0.6	N/A	1.01	0.91	0.28	1.01	1.13	0.60
Audio THD+N @ CCIR 4	N/A	1.12	0.6	N/A	1.01	0.91	0.27	1.01	1.12	0.60
Stereo Separation	N/A	18.8	18.3	N/A	21.2	19.43	1.55	18.77	21.2	18.3
Stereo Separation @ TOV	N/A	18.8	18.6	N/A	21.4	19.60	1.56	18.77	21.4	18.6
Stereo Separation @ CCIR 4	N/A	19.0	18.6	N/A	21.4	19.69	1.51	19.01	21.4	18.6
Adjacent channel:										
D/U @ TOV	-0.4	-3.4	-3.4	-3.4	-3.4	-2.8	1.34	-3.4	-0.4	-3.4
D/U @ TOA	<-10	<-10	<-10	<-10	<-10	<-10		<-10	<-10	<-10
D/U @ CCIR 4	<-10	-5.5	<-10	-7.5	-7.5	-6.83	1.15	-7.5	-5.5	-7.5
Audio THD+N	N/A	1.08	0.6	N/A	0.97	0.88	0.25	0.97	1.08	0.60
Audio THD+N @ TOV	N/A	1.08	0.6	N/A	0.98	0.89	0.25	0.98	1.08	0.60
Audio THD+N @ TOA	N/A	1.12	0.61	N/A	1	0.91	0.27	1.00	1.12	0.61
Audio THD+N @ CCIR 4	N/A	1.09	0.61	N/A	0.98	0.89	0.25	0.98	1.09	0.61
Audio THD+N @ 0dB D/U	N/A	1.08	0.61	N/A	0.95	0.88	0.24	0.95	1.08	0.61
Stereo Separation	N/A	17.2	16.1	N/A	22.5	18.59	3.40	17.17	22.5	16.1
Stereo Separation @ TOV	N/A	20.5	17.3	N/A	25.2	21.01	3.95	20.51	25.2	17.3
Stereo Separation @ CCIR 4	N/A	21.8	20.8	N/A	26.1	22.90	2.79	21.80	26.1	20.8
Stereo Separation @ 0dB D/U	N/A	19.2	17.1	N/A	24.1	20.10	3.58	19.16	24.1	17.1

Figure 6. Test results for 4096 carriers and 64 QAM modulation.

256 Carriers, 4-QAM	TV-1	TV-2	TV-3	TV-4	TV-5	Mean	Std Dev	Median	Max	Min
Co-channel										
D/U @ TOV	44.2	46.2	45.2	44.2	43.2	44.6	1.14	44.2	46.2	43.2
D/U @ CCIR 4	42.2	44.2	43.2	37.2	42.2	41.8	2.70	42.2	44.2	37.2
Audio THD+N	N/A	1.14	0.6	N/A	1	0.91	0.28	1.00	1.14	0.60
Audio THD+N @ TOV	N/A	1.14	0.6	N/A	1.01	0.92	0.28	1.01	1.14	0.60
Audio THD+N @ CCIR 4	N/A	1.13	0.6	N/A	1	0.91	0.28	1.00	1.13	0.60
Stereo Separation	N/A	18.8	18.3	N/A	21.2	19.44	1.55	18.77	21.2	18.3
Stereo Separation @ TOV	N/A	18.8	18.5	N/A	21.2	19.49	1.50	18.77	21.2	18.5
Stereo Separation @ CCIR 4	N/A	18.8	18.6	N/A	21.4	19.60	1.56	18.77	21.4	18.6
Adjacent channel										
D/U @ TOV	<-10	-0.1	<-10	-7.1	-7.1	-4.76	4.04	-7.1	-0.1	-7.1
D/U @ TOA	<-10	<-10	<-10	<-10	<-10	<-10		<-10	<-10	<-10
D/U @ CCIR 4	<-10	-7.1	<-10	-9.1	<-10	-8.10	1.41	-8.1	-7.1	-9.1
Audio THD+N	N/A	1.06	0.6	N/A	0.96	0.87	0.24	0.96	1.06	0.60
Audio THD+N @ TOV	N/A	1.07	0.61	N/A	0.97	0.88	0.24	0.97	1.07	0.61
Audio THD+N @ TOA	N/A	1.11	0.61	N/A	0.98	0.90	0.26	0.98	1.11	0.61
Audio THD+N @ CCIR 4	N/A	1.07	0.61	N/A	0.98	0.89	0.24	0.98	1.07	0.61
Audio THD+N @ 0dB D/U	N/A	1.08	0.6	N/A	0.96	0.88	0.25	0.96	1.08	0.60
Stereo Separation	N/A	17.2	16.6	N/A	22.8	18.88	3.43	17.23	22.8	16.6
Stereo Separation @ TOV	N/A	17.5	19.0	N/A	25.2	20.58	4.07	18.99	25.2	17.5
Stereo Separation @ CCIR 4	N/A	18.8	19.0	N/A	26.1	21.29	4.13	18.99	26.1	18.8
Stereo Separation @ 0dB D/U	N/A	17.7	16.6	N/A	23.4	19.23	3.67	17.68	23.4	16.6

Figure 7. Test results for 256 carriers and 4-QAM (QPSK) modulation.